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BIRDS AND AIRCRAFT ON MIDWAY ISLANDS

1957-58 Investigations

SPECIAL SCIENTIFIC REPORT: WILDLIFE No. 44

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1957-58 INVESTIGATIONS

By

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SPECIAL SCIENTIFIC REPORT--WILDLIFE NO. 44

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C O N T E N T S

ABSTRACT

The United States Naval Air Station at Midway Atoll in the 1957-58 season experienced collisions between albatrosses (Laysan albatross, Diomedea immutabilis, and black-footed albatross, Diomedea nigripes) and propeller-driven aircraft at the rate of 40 percent of all daylight landings and takeoffs during the November peak and at an average rate of 17 percent. Damage to aircraft was at the rate of 7 percent of all strikes or 1 percent of all daylight landings and takeoffs.

Destruction of albatrosses or their eggs increases the hazard to aircraft initially by making more birds unemployed, and would take many years to achieve total relief because of the large number of non-nesting birds at sea at all times, and the long period required for young to reach breeding age, or even to come ashore for the first time.

Leveling and clearing the land to eliminate updrafts on which birds are prone to soar is the only method known so far of obtaining any measure of relief immediately. It is believed this procedure might reduce the number of albatross strikes by 80 percent.

At least 90 percent of the world population of both species of albatross uses only four atolls: Midway, Pearl and Hermes, Lisianski, and Laysan. Midway, utilized by 35 percent of the nesting Laysan albatrosses and 16 percent of the nesting black-footed albatrosses, is second in importance only to Laysan as a production area. Thus, Midway comprises a very substantial portion of the remaining breeding ground of the world population of these species and from the standpoint of their perpetuation its loss as a breeding area would be serious. Elimination of albatrosses from Midway is only to be considered if essential to national defense.

The sooty tern, Sterna fuscata, population at Midway Atoll is about 150,000 birds on each island. The species is abundant and widespread in all tropical oceanic areas. The Midway populations are an insignificant part of the whole.

Although sooty terns are frequently struck by aircraft, no damage was reported during 1957 and 1958 seasons. With the advent of jet aircraft sooty terns would be a distinct hazard.

It was found that sooty terns could be kept from nesting and eventually caused to abandon Sand Island for the remainder of the season by a persistent program of shooting and harassing the birds on the nesting area. If elimination of sooty terns is necessary for the safety of jet aircraft at Midway it is recommended that killing and harassment be continued on Sand Island, on an annual basis, for as many years as necessary to keep the birds from nesting there.

INTRODUCTION

This report contains the results of research on the relation between bird populations and aircraft operations at the U. S. Naval Station, Midway Islands. The investigation was carried out by the Bureau of Sport Fisheries and Wildlife, U. S. Fish and Wildlife Service, Department of the Interior, with funds provided by the Bureau of Aeronautics, Department of the Navy. The results of field work from July 1957 through July 1958 are reported herein; this work was a continuation of previous studies, the results of which were published in "Birds and Aircraft on Midway Islands, 1956-57 Investigations" by Karl W. Kenyon, Dale W. Rice, Chandler S. Robbins, and John W. Aldrich, U. S. Fish and Wildlife Service as Special Scientific Report--Wildlife No. 38, January 1958.

The species of greatest concern are the Laysan albatross, Diomedea immutabilis, the black-footed albatross, Diomedea nigripes, and the sooty tern, Sterna fuscata, and the studies have been focused on these species.

Control of birds usually requires knowledge of size of populations, longevity, production, movements, behavior, and other facets of the life history of the species. Consequently, a complete analysis of these factors was undertaken.

Only those aspects of the study of immediate concern to the problem of aircraft operation are discussed here. Several other papers, covering in more detail the basic biological studies on the albatrosses, as well as other aspects of ornithology and wildlife conservation in the Leeward Chain of the Hawaiian Islands, are in preparation for publication in ornithological journals.

In October 1957, Johnson A. Neff, Denver Wildlife Research Laboratory, took over leadership of the project. Neff spent the periods 18 November to 13 December 1957, and 29 April to 16 May, 1958, on Midway. Dale W. Rice was in the field from 17 November 1956 to 21 July 1958. Willis C. Royall was on Midway from 18 November 1957 to 8 February 1958. Richard E. Warner, biologist with the Hawaii Division of Fish and Game, was temporarily employed for the period 13 May to 7 June 1958 to assist with studies on Laysan Island.

Captain John A. Gamon, Jr., Commanding Officer of the Midway Islands Naval Station, and his entire staff extended complete cooperation throughout all phases of the study. Naval personnel, their dependents, and civilians stationed on Midway assisted in many ways, both in an official capacity and voluntarily. Special thanks are due Lieutenant Commander J. B. Maze and Lieutenant (jg.) R. T. Takahashi, who served most efficiently as liaison officers. The U. S. Coast Guard generously provided transportation to Laysan Island and French Frigate Shoals; special acknowledgment should be made of the courtesy

and cooperation extended by the officers and men of the Cutters Matagorda and Chautauqua. P. T. Burtis and F. W. Landers generously lent their services for field work on Laysan Island. O. L. Austin, Jr., F. R. Fosberg, J. T. Marshall, Jr., M. Moynihan, G. C. Munro, and A. F. Robinson kindly supplied information on the status of albatrosses on several islands outside the Leeward Chain

PART I. ALBATROSS STUDIES

A. Albatross Populations in the North Pacific Ocean

During the 1957-58 nesting season, a census of albatrosses was conducted on all of the islands and atolls of the Leeward Chain of the Hawaiian Islands, and also on the island of Kaula in the main group. Mr. Aylmer F. Robinson, of Makaweli, kindly furnished information on the status of albatrosses on the island of Niihau. The census therefore covered all known breeding colonies of albatrosses in the Hawaiian Archipelago.

Outside the Hawaiian Islands, both Laysan albatrosses (Diomedea immutabilis) and black-footed albatrosses (D. nigripes) formerly nested on Wake, Marcus, and Johnston Islands. Albatrosses no longer occur on these islands, according to observers who have visited them in recent years. Laysan albatrosses once nested on Tori Shima in the Izu Islands, but were extirpated. Black-footed albatrosses also nested there, as they once did on Iwo Jima in the Volcano Islands, and on Muko Shima (and perhaps other islands) in the northern Bonin Islands; they were extirpated from the latter two archipelagos, but at least one pair was reported nesting on Tori Shima in January 1955. The only other recorded breeding station for black-footed albatrosses was Pokak (or Taongi) Atoll, in the northern Marshall Islands, where they no longer occur.

It thus becomes apparent that (except for a few black-footed albatrosses on Tori Shima) both the Laysan albatross and the black-footed albatross have become extinct throughout their former breeding range outside the Hawaiian Archipelago, and at the present time are virtually confined as breeding species to the Leeward Chain of islands. The present census of albatross nesting populations therefore represents essentially the total world population of these two species.

Census Methods

As described in detail in a previous report (Kenyon, et al. 1958), depending on the terrain, two methods were used to determine the size of the nesting albatross population: (1) aerial surveys, and (2) ground counts.

Aerial surveys were conducted at all of the islands in the Leeward Chain. The aircraft used were Navy UF-1 Grumman Albatross amphibians, flying at about 120 knots. Overlapping series of oblique photographs were taken at each island from altitudes of 200 to 500 feet. Albatrosses were subsequently counted on these photographs. It was assumed, on the basis of ground counts made at Midway during the same season, that 25 percent of the albatrosses counted on these photographs were non-nesting birds. The number of nests present on any

island was therefore considered to be 75 percent of the number of birds visible on the aerial photographs. This method is believed to be quite accurate for censusing islands with open terrain; on islands with considerable scrub growth, a large number of birds will be missed, and ground counts are essential. On two islands (Nihoa and Kaula), owing to the ruggedness of the terrain, the small number of albatrosses present, and the possibility of confusion with boobies, no counts could be made from the photographs. The figures presented for these islands are rough visual estimates made with 7x50 binoculars from the open hatch of the aircraft.

Ground counts were conducted in two ways: (1) Total counts of all nests were made where practical (black-footed albatrosses on Midway, and both species on Kure), and (2) sample-plot censuses were conducted where complete coverage was impractical. On Midway, randomly distributed one-fifth-acre circular plots were used. On Laysan Island, 50-foot-wide strip transects were laid out so as to cover the island in uniform fashion.

Results

During the 1956-57 season, population estimates included unemployed birds known to be on the islands (Kenyon et al. 1958). Subsequent studies have shown that the unemployed birds present on the nesting islands at any given time are only a small and variable fraction of the total unemployed group, as they spend much time at sea. The true size of this segment of the population is yet unknown, but it is suspected to be much greater than was previously believed. For this reason, the population estimates presented here include only the number of breeding birds. This gives a concrete figure which can readily be determined by counting nests, and which can be compared directly from year to year and from island to island.

A summary of present breeding populations is presented in table 1. All estimates have been rounded to the nearest two significant digits, as the accuracy of the census methods does not justify more precise figures. The total number of nesting birds is approximately 560,000 Laysan albatrosses and 110,000 black-footed albatrosses.

It is difficult to determine what this figure means in terms of total population -- breeding and nonbreeding. Present data suggest that the total, including all categories of unemployed birds, is at least three times the number of birds nesting in any one season (see section on Studies of Control Methods - large-scale killing program). On this basis the total world population of Laysan albatrosses is tentatively estimated at 1,500,000, and that of black-footed albatrosses at 300,000. (This is over 100 percent more than the world populations of each of these species estimated in our previous report (Kenyon et al. 1958) owing to the change in our concept of the size of the portion of the population at sea.)

Furthermore, data from study plots on Midway indicate that, under normal conditions of nest mortality, 33 percent of the nesting birds fail to nest the following season. If we allow 5 percent for mortality, this means that the total population of sexually mature birds is about 42 percent greater than the number actually nesting during any one season. Therefore; the total effective nesting populations are about 800,000 Laysan albatrosses and 160,000 black-footed albatrosses.

Table 1.--Summary of Breeding Populations of Albatrosses in the Hawaiian Archipelago, 1957-58.

Island or atoll	Number of breeding birds	
	Laysan albatrosses	Black-footed albatrosses
Kure Atoll	700	140
Midway Atoll	200,000	17,000
Pearl and Hermes Reef	36,000	14,000
Lisianski Island	60,000	5,500
Laysan Island	260,000	67,000
Gardner Pinnacles	6	--
French Frigate Shoals	1,200	3,000
Necker Island	5,000	750
Nihoa	1,000	100
Kaula	--	200
Niihau	1,000	--
Moku Manu	0*	--
TOTAL	ca. 560,000	ca.110,000

* One pair nested in 1946-47 and 1947-48; one bird observed in December 1955, and three in December 1956. (Hawaii Audubon Society records.)

From the figures in table 1, it may be seen that Laysan Island is the most important breeding station for North Pacific albatrosses. It is utilized by 46 percent of the total breeding population of Laysan albatrosses, and by 61 percent of the total breeding population of black-footed albatrosses.

Midway Atoll ranks second with 36 percent and 15 percent, respectively, of the total breeding populations of the two species.

Only four atolls - Laysan, Midway, Lisianski, and Pearl and Hermes Reef - are the breeding grounds of 96 percent and 94 percent, respectively, of the total world populations of Laysan and black-footed albatrosses. It is obvious that the future of North Pacific albatross populations hinges largely upon the maintenance of adequate breeding colonies on these four atolls, particularly Laysan and Midway.

A more detailed report on albatross populations throughout the Leeward Chain will be published elsewhere by Karl W. Kenyon and the writer.

B. Ecological and Life History Studies

The present report contains only brief summaries of those aspects of life history and ecology that have an immediate bearing on the aircraft hazard problem or on the application of control measures. A more detailed report covering the basic biological aspects will be published separately.

Age at Which Albatrosses First Return to the Breeding Grounds

Present data are inadequate to determine the age at which young albatrosses normally return to the nesting islands for the first time. None of the 5,000 albatross chicks color-banded in May-June 1957 returned during the 1957-58 nesting season. The youngest banded birds of known age recaptured on the islands were a single 4-year-old Laysan albatross and a single 4-year-old black-footed albatross. No known 5-year-old albatrosses have been recaptured. Returns of birds banded as chicks are fairly evenly distributed after the fifth year following banding (table 2). This suggests that the majority of young birds return for the first time sometime between the ages of 4 and 6 years. The royal albatrosses (Diomedea epomophora) of New Zealand first return to their breeding grounds between the ages of 4 and 8 years (Richdale 1952). Further information is necessary to determine what proportion of our North Pacific albatrosses first return at each age, and if any return before the age of 4 years. Without this information it is impossible to determine the number of immature birds at sea.

Table 2.--Age at Return (on Sand Island, Midway Atoll) of Albatrosses Banded as Chicks (includes returns through 1957).

Age	Number returned 1/	
	Layson albatrosses	Black-footed albatrosses
1	0	0
2	0	0
3	0	0
4	1	1
5	0	0
6	2	3
7	2	3
8	5	2
9	2	1
10	0	5
11	5	4
12	0	1
13	1	0 2/
14	0	0
15	3	0
.		
.		
.		
21	1	0

1/ The number of each age group retaken should not be considered as comparable numerically since the size of the samples banded were not the same in the different years, nor was equal effort expended each year obtaining return records.

2/ No black-footed albatross chicks were banded before 1944.

Age At Which Albatrosses First Nest

The only positive information on the age at which Laysan albatrosses first nest is the record of a bird banded as a chick in 1951 and found incubating an egg in December 1957, 7 seasons after hatching. It is almost certain that this bird did not nest the previous season, as all nesting birds on that area were thoroughly checked repeatedly during the incubation period in 1956.

During the killing program, 14 Laysan albatrosses banded as chicks 7 seasons previously were killed. These included 7 males, 5 females, and 2 of unknown sex. All of them were apparently unemployed birds when killed. Three of these birds (2 males, 1 female) had bare incubation patches, suggesting that they may have nested that season (it remains to be verified how reliable the condition of the incubation patch is as an indication of breeding).

No data are available for black-footed albatrosses. One female New Zealand royal albatross is reported to have nested for the first time in her ninth year (Richdale, 1952:120). Much more work is required to determine what proportion of birds in each age group are sexually mature.

Selection of Nesting Sites by Immature Birds

When ready to nest, do albatrosses return to the site where they were hatched? This question has long been a subject of much discussion and speculation on Midway. Present evidence indicates that they do not. No albatrosses banded as chicks have yet been found nesting at the same site in subsequent years. On the other hand, 2 Laysan albatrosses have been found nesting at some distance from their hatching sites. One bird hatched at Gooneyville Lodge, Sand Island, in 1937 was found nesting 500 yards away, behind the Officers' Club, in 1957-58. Another bird hatched on Eastern Island in 1951 was found nesting on Sand Island, 3 miles away, 7 seasons later (1957-58). Of 97 other banded chicks which hatched at the same time and place as this bird, 14 were killed on Sand Island during the killing program. These incidents indicate a tendency for immature birds to wander and eventually settle down at places some distance from their hatching sites. What proportion, if any, might settle down at other atolls is not known, but it is perhaps significant that none of the thousands of albatrosses which have been banded at Midway was found on Kure Atoll or on Laysan Island despite special search. From these facts it would appear that population spread of these two species of albatross is by young birds which have never nested before rather than of adults which have nested previously.

Permanence of the Pair Bond

On several study plots, 341 marked pairs of Laysan albatrosses were followed through two nesting seasons (1956-57 and 1957-58). During the second season, the status of the previous season's pairs was as follows:

	Number	Percent
Pairs returned intact	323	94.7
Pairs returned "divorced" (both birds with new mates)	7	2.1
Only one member returned (with new mate)	11	3.2

It therefore appears that the pair bond normally remains intact until broken by the death or disappearance of one of the partners.

It is of interest to note that of 76 birds whose mates were killed in an experiment during the incubation period of the 1956-57 season, only 10 (13 percent) remated and nested the following season, whereas at least 29 of the remaining 66 birds returned to the same area as unemployed birds. It thus appears that less than one year is normally insufficient time for unmated birds to establish a pair bond and to nest. Therefore killing one of a pair would reduce the amount of reproduction the next year but would increase the number of unemployed birds on the breeding area.

Permanence of the Nesting Site

Adult albatrosses, once they have selected a nest site, appear to return to the same site year after year. Many birds banded as adults in 1938 at the site of Gooneyville Lodge (now destroyed) were still nesting there during the 1956-57 and 1957-58 seasons; none have ever been found nesting elsewhere.

During the 1956-57 season, the locations of the nests of 166 marked pairs of Laysan albatrosses on the post office lawn were plotted on a large-scale map. The following year (1957-58) 101 of these pairs returned intact and nested. The locations of their nests were again mapped. By comparing the two seasons' maps, the distances the birds moved their nest sites between subsequent seasons was measured. The results were as follows:

Distance moved	Number of pairs	Percent
0-1 meter	44	43.5
1-2 meters	34	33.7
2-3 "	11	10.9
3-4 "	7	6.9
4-5 "	3	3.0
5-6 "	2	2.0
6+ "	0	0

Over 50 percent of all pairs constructed their nests within 1.3 meters of the previous year's site. In general, those nesting adjacent to an obvious landmark, such as a tree or bush, or the corner of a building, showed less deviation than those which nested in the middle of a large expanse of open lawn.

The effects of the elimination of nesting areas by construction of buildings, parking areas, etc., is not known. Presumably the birds would eventually take up residence elsewhere, perhaps in the nearest suitable area, but they did not do so immediately in areas of displacement due to 1957 construction. It is probable that one or more seasons must elapse before new nesting sites are selected by pairs which have lost their former sites.

Frequency of Breeding

The question whether North Pacific albatrosses are annual or biennial nesters has been the subject of much controversy, without any unequivocal evidence either way. The large royal albatross of New Zealand is reported (Richdale, 1950:30) to be a biennial nester as long as the chick is successfully fledged, but if the egg is destroyed or the chick dies, the parents may nest again the following season. This species has an 11-month nesting cycle. The wandering albatross (Diomedea exulans) is also of necessity a biennial nester, as its breeding cycle is of 13 months' duration. It was thought that the Laysan and black-footed albatrosses might also be biennial nesters, but heretofore no one had followed through two successive nesting seasons any marked pairs of the small albatrosses including the two North Pacific species. In contrast to the larger albatrosses, these relatively smaller species have a nesting cycle of approximately 9.5 months, so that they should be capable of nesting in subsequent years even if they fed a chick to the end of the fledgling period.

One of the chief objectives of the present studies was to obtain positive data on this point. To this end, a follow-up check was made in the 1957-58 season of 497 pairs of Laysan albatrosses marked the previous (1956-57) season. These included 164 pairs on a control plot (the post office lawn), and 333 pairs on experimental plots where the eggs or chicks were destroyed at different stages in the breeding cycle. After eliminating from consideration data from 78 nests which could not be used for various reasons, 419 nests were left for calculating nesting success. Of these 419 nests, on 18 only one bird could be used in the calculations, as the other pair member either was not marked the first season, or was not captured the second season. The results are thus based on 820 individual birds of known nesting success.

These studies have shown conclusively that a large proportion of Laysan albatrosses nesting in any one season, whether successful or not in rearing a chick, return to nest the following year. Presumably the same is true of black-footed albatrosses, although no data are available for that species.

The percentage of birds returning and renesting the second year varied from 87 to 63 percent (table 3). There is a decreasing tendency to renest with an increase in nesting "success" (i. e., an increase in the length of the portion of the breeding cycle that was successfully completed the previous season). Thus, birds which lost their eggs early in the 1956-57 incubation period showed the highest percentage of renesting the following season, while those which successfully fledged a chick in the 1956-57 season showed the lowest percentage of renesting.

It appears that nest destruction would tend to increase the number of birds nesting the following season.

Table 3.--Relation Between Nesting Success and Renesting the Following Season in Laysan Albatrosses

Fate of nest, 1956-57	Number of pairs	Number of birds [1]	Returned, 1957-58	
			Number of birds	Percent
Chick successfully fledged	75	150	94	63
Chick died during post-guard stage [2]	43	86	70	81
Chick died during guard stage [2]	62	126	99	79
Eggs sterile	72	147	128	87
Eggs destroyed late in incubation stage	71	144	108	75
Eggs destroyed early in incubation period	78	167	145	87

1/ Includes birds comprising marked pairs (column 1) plus birds whose mates could not be used in the calculations because they were not banded the first season or were not captured the second season.

2/ The guard stage is that period from when the chick is hatched until it is no longer guarded by one parent while the other is away gathering food; the post-guard stage is after the parents have left the chick unguarded (Richdale 1952:68 & 77).

Sex Ratios

In order to determine whether a highly unbalanced sex ratio was responsible for the large proportion of unemployed birds in the population, a random sample of 182 apparently unemployed Laysan albatrosses was collected in a previously undisturbed area on two different days.

This sample consisted of 82 males and 100 females (45 percent males). In addition, 39 more birds were selectively collected; these consisted of birds which were dancing together, birds "keeping company," etc. This sample contained 19 males and 20 females (49 percent males). The total of these samples was 101 males to 120 females (46 percent males).

It was thought that a large number of paired birds which were unemployed owing to destruction of their nests might tend to equalize the apparent sex ratio of the unemployed birds. The first day's sample was segregated into birds with bare incubation patches (birds which presumably had nested) and birds with downy or partially downy incubation

patches (birds which presumably had not nested). The ratio of males to females was 14:7 (67 percent males) for the former (nesters), and 39:61 (39 percent males) for the latter (non-nesters).

It is apparent that the high proportion of unemployed birds in the Laysan albatross population cannot be blamed on a highly disproportionate sex ratio.

Population Dynamics

The subject of albatross population dynamics is one in which we are almost totally ignorant, yet it is a phase on which, from the management standpoint, it is necessary to have a complete understanding. This lack of information cannot be remedied until large numbers of marked birds of known age and origin have been followed through many seasons. To create a reservoir of such birds in the population, a large-scale banding program was initiated in the 1956-57 season. This program was continued during the 1957-58 season with the banding of the following numbers of albatross chicks at the following localities:

Species	Eastern I., Midway Atoll	Laysan Island	Total
Laysan albatross	4,000	2,000	6,000
Black-footed albatross	600	900	1,500
Total	4,600	2,900	7,500

To facilitate recognition of living birds, each of the young albatrosses of the 1958 year class banded on Eastern Island was marked with a yellow plastic band in addition to the standard U. S. Fish and Wildlife Service numbered aluminum band.

This brings the total of young albatrosses banded during the past two seasons to over 13,000. It is unfortunate that termination of studies at Midway will prevent continued observations of these marked birds in sufficient detail to fill in the large gaps in our knowledge of their population dynamics.

Distribution at Sea

The pelagic distribution of both the Laysan albatross and the black-footed albatross has long been known in a general way from observations made at sea. However many details remain to be worked out, and many questions concerning their sojourns at sea, where they spend such a large part of their entire lifetime, remain unanswered.

Pelagic recoveries of banded albatrosses now (October 1958) include 49 black-footed and 21 Laysan albatrosses. These cover the entire length and breadth of the North Pacific Ocean, from latitude 25° north to the southern Bering Sea, and from the waters off California to the waters off Japan. The majority are from the western Pacific,

between Midway and Japan, apparently because the greater abundance of Japanese fishing vessels in this area increases the likelihood of their capture.

As additional recoveries of banded birds come in, the answers to some of the many questions concerning their life at sea are beginning to take shape. For other questions, it will take many years to accumulate sufficient evidence to provide answers. The large-scale banding program started in 1957 and continued in 1958 has greatly increased the rate of pelagic recoveries of marked birds. These recoveries are being recorded and analyzed, and the results will be published when a significant amount of data has been accumulated.

Breeding Cycle

During the 1957-58 season, intensive studies of the breeding cycles of both species of albatrosses were undertaken. These involved twice-daily observations on 116 Laysan albatross nests and 39 black-footed albatross nests, on each of which both pair-members were banded and dye-marked.

These studies covered arrival at the nesting grounds, territory, mating, nests and nest-building, egg-laying, incubation, hatching, and care and development of the chicks during the guard stage and early post-guard stage (for definition see footnote 2/ on page 12). Lack of time and personnel, and a prolonged absence from the island, made it impossible to continue the study beyond the middle post-guard stage.

Although these studies are important in understanding the overall biology of albatrosses, and are thus essential for the application of intelligent management plans, they have no immediate direct application to the aircraft problem. Therefore, they will not be reported here, but will be published in detail elsewhere.

Mortality of Juvenile Albatrosses

During June and July of 1957, an effort was made to determine the mortality rate of juvenile albatrosses since egg-laying.

Black-footed albatross juvenile mortality on Sand Island.--To determine mortality of young black-footed albatrosses on Sand Island, a complete count was made of all young birds from 28 June to 1 July. The birds were counted by discrete areas; the areas were the same as those used during the January-February nest counts (Kenyon, et al. 1958). Following are the counts compared with the earlier nest counts:

Area	Jan-Feb.	June-July	
1	1300	296	
2	1370	424	
3	178	13	
4	56	0	(killed during experimental killing program)
5	285	140	
6	23	13	
7	270	81	
8	157	83	
Total	3,639	1,050	

These figures indicate a mortality of over 70 percent on Sand Island. However, some of the young black-foots had already departed when the counts were made in late June and early July. Using as a correction factor the proportion of banded birds whichleft Eastern Island between early June and early July (see below), the total number of young black-foots successfully fledged should be increased by 69 percent, or an additional 725 birds. This gives a total of 1,775 surviving young black-footed albatrosses on Sand Island. The mortality rate between January-February and June-July was approximately 50 percent.

Black-footed albatross juvenile mortality on Eastern Island.-- A total count of surviving young black-footed albatrosses was also made on Eastern Island, on 3 July. On 3 and 4 May, 1,000 young black-foots were banded on Eastern Island. When the counts were made on 3 July, banded and unbanded birds were counted separately, in order to determine what proportion had already departed. The total number which survived, and the mortality rate, were calculated as follows:

a)	Total count of nests, 27 February			1,669
b)	Total banded, 3-4 June		1,000	
c)	Total banded birds counted, 3 July	507		
d)	Total unbanded birds counted, 3 July	239		
e)	Total birds counted, 3 July	746		
f)	Total estimated, 3 July		1,471	
	$f = \frac{be}{c}$			
g)	Estimated mortality, Feb.-July			12%

$$g = 100 - \frac{(f.100)}{(a)}$$

Laysan albatross juvenile mortality on Sand Island.-- Mortality figures of juvenile Laysan albatrosses on Sand Island are available only from the study area on the post office lawn, which was followed quite closely throughout the season. It may be regarded as representative of the entire residential area of the island, as regards

juvenile mortality. The data are as follows:

a)	Total eggs laid	164
b)	Total young (March)	119
c)	Mortality through March $c=100-\frac{(b\cdot 100)}{(a)}$	27%
d)	Young remaining, 9 July	76
e)	Number of young which had already left (based on data from officers' club study plot) $e=0.3\cdot d$	23
f)	Estimated number of young successfully fledged $f=d+e$	99
g)	Mortality rate, laying to fledging $g=100-\frac{(f\cdot 100)}{(a)}$	40%

Mortality in areas where much construction work was going on was undoubtedly higher than that in the residential area. On the other hand, mortality was probably lower in some of the more remote, less disturbed, areas. For the island as a whole, it is estimated that the mortality rate was somewhat higher than 40 percent, perhaps 50 percent.

Laysan albatross juvenile mortality on Eastern Island.--In the central triangle of Eastern Island, all Laysan albatross nests were counted on 17 January. In early June, all chicks in this area were banded, and subsequently a careful search was made for dead banded chicks. These data permit the derivation of a mortality figure for a representative area on Eastern Island as follows:

a)	Total nests counted, 17 January	2,676
b)	Total chicks counted (and banded), June	2,100
c)	Number banded chicks found dead on area	54
d)	Number banded chicks found dead elsewhere on island	3
e)	Total number found dead	57
f)	Maximum number successfully fledged $f=b-e$	2,043
g)	Mortality, egg to fledging $g=100-\frac{(f\cdot 100)}{(a)}$	24%
h)	Minimum mortality, early June to fledging $h=100-\frac{(f\cdot 100)}{(b)}$	3%

The preceding mortality figures, for both species on both islands, do not take into consideration the apparently high mortality of young birds immediately after they leave the island. Many young birds, either dead or so water-soaked and bedraggled that they could

not fly, were found floating in the lagoon or washed up on the reef and the beaches. This mortality is difficult or impossible to assess. One possible way to compare this mortality on a year-to-year basis could be to count the number of dead birds along the beaches. These counts would include birds which left the island, were drowned, and washed up on the beaches, and also starving birds which wandered down to the beaches and died without leaving the island. Such counts would include only a small fraction of the total post-fledging mortality, but it should provide a fairly reliable index for year-to-year variations. On 16 July the entire beach of Eastern Island was walked, and all dead young albatrosses were counted, with the following results: Laysan albatross, 409; black-footed albatross, 14.

The date was believed to be about right for counting the Laysans, as a maximum number of dead chicks were present at that time. However, for the black-foots, a count made two or three weeks earlier would give a better index.

On the basis of hearsay, a heavy mortality due to sharks was anticipated. It was said that sharks throng into the lagoon when the young gooneys are just learning to fly. Such did not appear to be the case in the summer of 1957. The members of the underwater demolition team which was working in the lagoon all spring and summer reported no large sharks during June and July, although they had seen a few earlier in the spring. Of course there are always a few sharks, including an occasional large one, around the reef. But there was no evidence to indicate that there was an influx of sharks, or that they were feeding on young albatrosses.

The situation was different in the summer of 1958, however. At Midway, large sharks were frequently observed from low-flying aircraft. Many of these, identified as tiger sharks (Galeocerdo cuvieri), were from 10 to 15 feet long. A number of fair-sized hammerhead sharks (Sphyrna lewini) also were seen. Large sharks were also common during this period at Kure Atoll and at Pearl and Hermes Reef. Several people reported seeing sharks attacking waterlogged juvenile albatrosses in the lagoon.

On the basis of general impressions, it would seem that the majority, probably at least two-thirds, of the albatrosses which reach the flying stage are successful in leaving Midway Atoll.

Summary of mortality of juvenile albatrosses.--On the basis of counts made at different times of the nestling season, and on known mortality rates for different periods, as presented above and in the 1956-57 report, we may attempt an estimate of the total number of young albatrosses which were fledged at Midway Atoll in the 1956-57 season. The number of eggs laid is based on the November population estimates (see Kenyon, et al. 1958). The number of young fledged is based either on total counts (for black-foots, as presented above), or on estimates made on the basis of known mortality rates on sample plots (Laysans) subsequent to total counts on those areas. From these figures, the

survival and mortality rates from egg-laying to fledging are calculated. These data are as follows:

Black-footed albatross, on --	Number of eggs laid	Number of young fledged	Mortality rate	Survival rate
Sand Island	4,280	1,780	58%	42%
Eastern Island	2,290	1,470	36%	64%
Total	6,570	3,250	51%	49%
Laysan albatross, on --				
Sand Island	60,000	36,000	40%	60%
Eastern Island	45,000	30,000	33%	67%
Total	105,000	66,000	37%	63%

These figures confirm the suspected higher mortality rates for the black-foots, as compared with the Laysans. However, it is interesting to note that there is very little difference in mortality rates between the two species on Eastern Island, which is not subject to much human disturbance.

Taking the Laysan albatrosses on Sand Island as an example, even if we assume that the juvenile mortality was 60 percent rather than 40 percent, we would get an estimate of 24,000 young which reached the flying stage. If we further assume that only two-thirds of these, or 16,000, survived their first few weeks after leaving the island, we still get an annual increment of about 7,000 or 8,000 over the estimated annual adult mortality on Sand Island (estimated at 8,000 to 9,000; see 1956-57 report). It seems apparent that, even under the abnormally heavy mortality which prevailed on Sand Island during the 1956-57 season, the biotic potential of the Laysan albatross is still sufficient to maintain the population. Mortality of adults at sea is very low - not over 5 percent a year, based on returns of birds banded at Gooneyville Lodge 18 years ago. The big unknown factor is the mortality of young birds at sea during the first few years of their life, before they return for the first time. Until that is known, we cannot predict how much mortality the population can sustain on Sand Island.

Nest Mortality Due to Tidal Waves

Under the term "tidal waves" are two distinct phenomena, the results of which are the same as far as nesting albatrosses are concerned. The first of these phenomena is the "tsunami," or seismic tidal wave. The second is the storm tide created by typhoons (or hurricanes, depending on whether they originate west or east of the 180th meridian). Their effects on nesting albatrosses are irregular and infrequent, but often disastrous and of far-reaching effect throughout the Leeward Chain.

During the course of studies on Midway, one tsunami struck the islands. This occurred at about 0700 on the morning of 9 March 1957. The sea level was raised 3 feet at Midway, and large waves flooded portions of the island. In certain areas many young albatrosses were washed away or drowned, but the tidewaters had little effect on the total number of young albatrosses.

During the same period, three typhoons or hurricanes occurred in the general area. None of these passed close enough to Midway to have any noticeable meteorologic effects, but one of them had marked oceanographic effects at Midway. This was typhoon Ophelia which generated high storm tides at Midway, and throughout the Leeward Chain, on 11-13 January 1958. During peak intensity, which lasted about 12 hours, 30-foot surf was breaking over the reef. Inside the lagoon, 12-foot breakers were pounding the beaches of Sand and Eastern Islands. In many areas the force of the waves breached the dunes and flooded large areas inland, from which the water could not escape. This storm brought disaster to the black-footed albatross nests on the open beaches, and also flooded many nests farther inland. After these storm tides, a count was made of all black-footed albatross nests in areas affected by the tides on Sand Island. These counts, compared with the counts made at the beginning of the season, are as follows (for areas, see Kenyon, et al. 1958, fig.1):

Area	Number of nests originally	Number of nests after storm	Percent loss
1	1797	1340	26
2	2504	812	68
3	261	52	80
4	89	(89) not affected	
5	539	(539) " "	
6	331	(331) " "	
7	399	158	60
8	268	(268) " "	
Total	6,188	3,589	42

A small part of the above mortality can be attributed to other causes before the storm, but the storm tides probably accounted for a mortality of over 35 percent of the 42 percent average. Laysan albatrosses nests were not seriously affected by these storm tides, except in small local areas.

The small low islets of Pearl and Hermes Reef are even more vulnerable to high water than are the larger, higher islands at Midway. To determine the effects of the storm tides on albatrosses nesting there, a flight was made over all the islets on 24 January 1958. Repeated passes, at an altitude of about 50 feet, were made over each

islet, and the amount of nest destruction was estimated visually for each islet, with the following results (compared with the November population estimates):

Island	Laysan albatrosses			Black-footed albatrosses		
	Number of nests before	Estimated percent destroyed	Estimated number remaining	Number of nests before	Estimated percent destroyed	Estimated number remaining
Kittery I.	--	--	--	450	100	0
Seal I.	450	50	225	375	80	75
Grass I.	1,185	10	1,067	1,935	50	967
South Sandspit	--	--	--	65	100	0
Southeast I.	14,225	5	13,514	2,270	35	1,475
North sandspit	--	--	--	120	100	0
North Island	2,060	5	1,957	1,930	20	1,544
Total	17,920	6	16,763	7,145	43	4,061

The inland-nesting Laysans suffered only minor nest destruction compared with the beach-nesting black-foots. On the open bare sandspits (including Kittery Island), all of the black-foot nests were destroyed. Total nest mortality for black-foots in the entire atoll was about 43 percent, not significantly different from that at Midway.

C. Albatross Problem in Aircraft Operations

Frequency of Albatross Strikes

During the period from 30 October 1957 to 17 April 1958, personnel in the Air Control Tower carefully observed with 7x50 binoculars every plane which landed and took off. All albatross strikes were recorded. The data gathered included time of strike, location on runway, wind direction and other meteorological data, species of albatross involved, portion of aircraft struck, and any damage incurred by the aircraft.

The number of strikes recorded is doubtless somewhat higher than the number of birds actually struck, as birds frequently come so close to moving aircraft that they are blown down and killed by the backwash from the prop or by the slipstream, without actually coming into contact with the aircraft. Such incidents would appear to be strikes to an observer in the tower, often a mile or more away. On December 1, 1957, Neff observed at close range, 23 birds killed; 4 did not actually touch the airplane.

The number of reported strikes in relation to aircraft operations is presented in table 4. In calculating strike frequencies, only daylight landings and takeoffs are considered, as albatross soaring activity is virtually nonexistant at night.

Soaring activity, and frequency of strikes, reaches a peak during the last half of November, after the birds have returned, and before they are occupied with nesting duties. This is followed by a marked drop in strike frequencies, which then slowly taper off during the remainder of the season. Data for the 1956-57 season (Kenyon, et al. 1958) showed a similar picture.

Table 4.--Number of Aircraft Landings and Takeoffs, and Number of Albatross Strikes, at Sand Island, Midway Atoll, 30 October 1957 to 17 April 1958.

Period	Landings and takeoffs		Albatross strikes			Strikes per daylight landing or takeoff
	Total	Daylight	Layson	Blackfoot	Total	
30 Oct-15 Nov	268	169*	8	4	12	0.07
16-30 Nov.	212	134*	52	1	53	.40
1-15 Dec.**	440	277*	52	1	53	.19
16-31 Dec.	171	102	23	2	25	.25
1-15 Jan.	183	116	18	1	19	.16
16-31 Jan.	255	139	19	2	21	.15
1-15 Feb.	265	195	25	1	26	.13
16-28 Feb.	154	106	10	2	12	.11
1-15 Mar.	306	192	32	5	37	.19
16-31 Mar.	357	223	28	1	29	.13
1-17 Apr.	322	206	19	4	23	.11
Total	2,933	1,859	286	24	310	.17

*Estimated

** This period included intensive refueling activity by Air Corps tankers over Midway, also the period of takeoff of more than 50 Naval aircraft evacuated from Oahu on November 30 because of hurricane Nina.

As pointed out in the previous report (Kenyon, et al. 1958), black-footed albatrosses are relatively unimportant as far as the aircraft problem is concerned. They accounted for only 24, or 8 percent, of the 310 strikes recorded during this period. However, this proportion is higher than the 1 percent of strikes contributed by black-footed albatross recorded in the 1956-57 season.

Damage Resulting from Albatross Strikes

During the period from 30 October, 1957 to 17 April, 1958 records of 256 strikes (out of the 310 listed in table 4) indicated the part of the aircraft struck, and the damage done. Eighteen (or 7 percent) of these 256 strikes were recorded as having damaged the aircraft. About 1 percent of all daylight landings and takeoffs resulted in damaging strikes. It is certain, however, that a number of incidents involving minor damage (dented wings and cowlings, etc.) were not reported to the Tower, and are thus not included in the tabulation (table 5).

Some of the strikes resulted in damage sufficiently severe to require the immediate grounding of the plane for repairs, but none caused damage serious enough to endanger the plane during landing operations. A very few of the strikes resulted in the grounding of aircraft for considerable periods of time, and for time-consuming and expensive repairs. The majority of the strikes caused only minor damage which was quickly repaired.

In addition to the regular bird strike reports assembled by the Air Control Tower (table 5), a special summary report was received covering bird strikes suffered by the planes of one squadron of the Airborne Barrier Service, flying off Sand Island between 18 February and 8 December, 1957. This report does not include a statement of the landings and takeoffs made by this squadron on Sand Island during the 10-month period, but these were many, frequently a number each day that the squadron was on active flight duty during the period. During the 10-month period this squadron listed 12 planes damaged by bird strikes. Four were grounded for 1 day, eight for as long as 3 days. Four other planes damaged during the November-December period of intense bird soaring were grounded for 15, 21, 29, and 60 days, respectively. The summary of listed costs and losses due to damage by bird strike totaled $82,819, of which $77,970 was counted as depreciation, calculated at $565 for each day that the plane was unable to fly. Total costs for repairs and replacements was $4,849, and necessary repair labor by Navy air mechanics totaled 1,073 hours.

Table 5.--Part of Aircraft Struck, and Damage Resulting from Albatross Strikes.

Part of aircraft struck	Number of strikes	Number of strikes resulting in damage	Percent of strikes resulting in damage	Percent of total damaging strikes
Propeller	86	0	0	0
Engine (including air scoops and cowling	49	4	8	22.2
Wing	42	4	10	22.2
Landing gear	27	0	0	0
Fuselage (except windshield)	25	0	0	0
Windshield	5	1	20	5.6
Antenna	5	5	100	27.7
Stabilizers	4	1	25	5.6
Flaps	1	1	100	5.6
Wingtip tanks, drop tanks, floats, and float struts	7	2	29	11.1
Radomes	5	0	0	0 *
Total	256 **	18	7	100

* Badly dented radomes have been reported subsequently.

** Total number of strikes in this table is smaller than that shown in table 4 because part of aircraft struck was not recorded in all bird strikes listed.

Location of Strikes in Relation to Terrain and Wind Direction

The locations of 247 albatross strikes which occurred on runway 6-24 were recorded by personnel in the Air Control Tower. Of this total, 220 (89 percent, or 44 per 1,000 feet of runway) occurred along the western 5,000 feet of the runway, adjacent to high trees, dunes, and revetments, which created updrafts, while only 27 (11 percent, or 9 per 1,000 feet of runway) occurred along the eastern 3,000 feet of the runway, where the shoulders have been leveled. Expressed in another way, albatross strikes are five times as likely to occur along portions of the runway where the adjacent terrain causes favorable soaring conditions, than they are along portions with wide level shoulders.

Figure 1 illustrates the relative proportion of strikes occurring at each 1,000-foot section of this runway. It can be seen that the highest number of strikes occur at the eastern end of the line of dunes along the south edge of this runway. The updrafts caused by this line of dunes result in its being a major flyway, and its eastern end is an "intersection" from which albatross flight lines fan out over the entire eastern half of the island. During periods of high wind in November, a veritable cloud of hundreds of albatrosses could be seen wheeling about this point.

Data on these same 247 albatross strikes indicated that 158, or 64 percent, occurred under wind directions which were more favorable for soaring (see Studies of Control Methods -- Terrain Modification), while 89, or 36 percent, occurred under wind directions which were less favorable for soaring. Albatross strikes are thus twice as likely to occur when wind directions are such as to create the strongest updrafts.

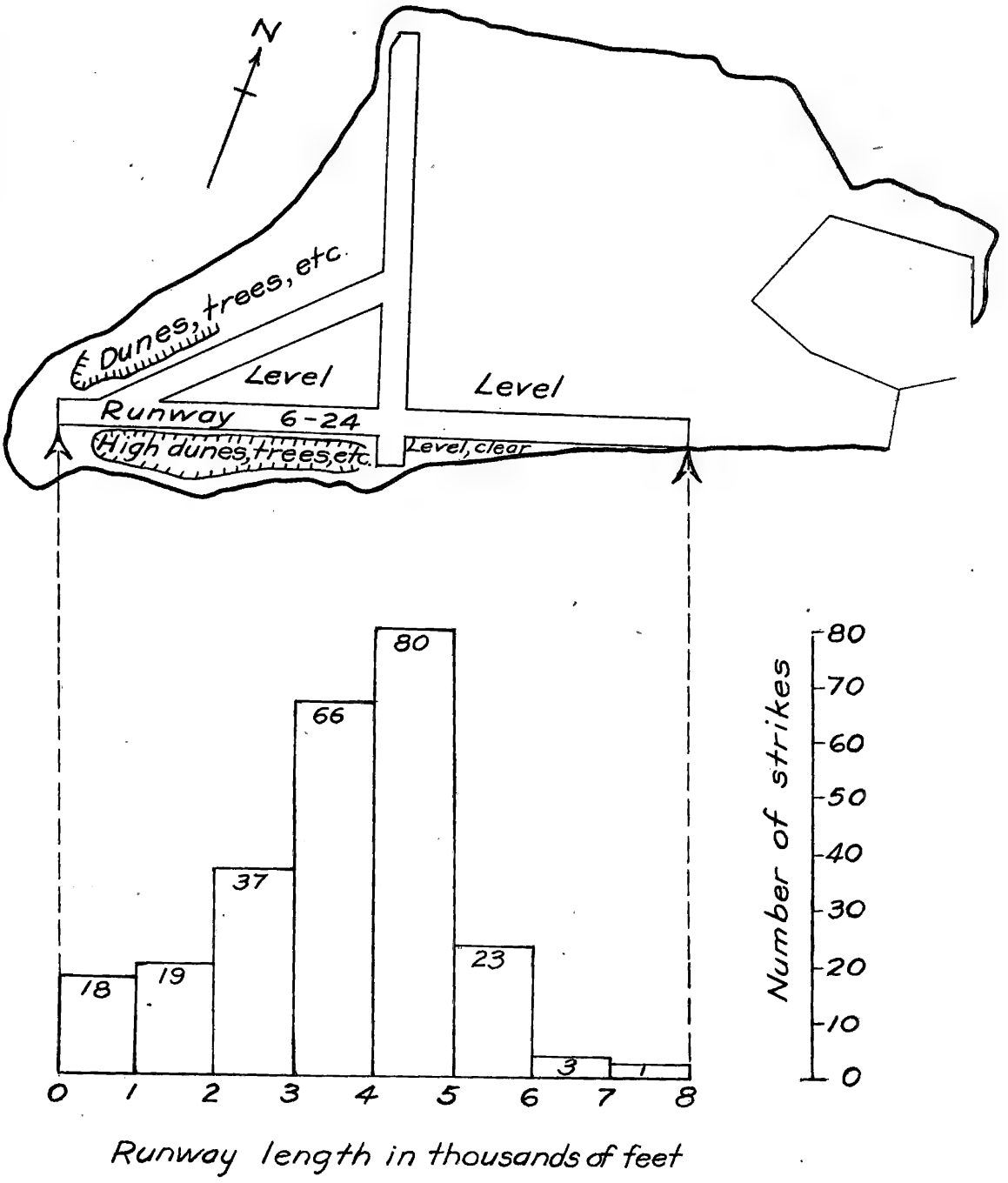
D. Studies of Control Methods

Large-scale Killing Program

In order to test the effectiveness of albatross elimination as a method of reducing the aircraft hazard, and also in hopes that it would provide some immediate alleviation of this hazard, the Navy requested that an experimental killing program be undertaken in the breeding season of 1957-58. Although the previous season's relatively small-scale experimental killing program (Kenyon, et al. 1958) indicated that no immediate practical results were likely to accrue therefrom, it was thought that a more extensive experiment was necessary.

Methods.--The killing program was limited to the area within 750 feet of the centerline of the western half of runway 6-24 (west of its junction with runway 15-33), with the exception that the entire

Figure 1. Location of 247 bird strikes on runway 6-24 in relation to terrain.



central triangle, a small portion of which extends beyond the 750-foot limit, was included. This triangle was the site of the previous season's experimental kill (Kenyon, et al. 1958). The killing area comprised part of zone 7, and all of zones 8 and 9, as delimited by the Midway Islands Naval Station (see figure 2). This area was selected because it is adjacent to the portion of the runway where the greatest frequency of strikes occurs (see Albatross Problem in Aircraft Operations -- Location of Strikes in Relation to Terrain and Wind Direction).

Only Laysan albatrosses were killed, except in the central triangle area (zone 8) where both species were eliminated; in zone 8 birds from a small black-foot colony flew to and from the beach at a critical point in plane takeoff action. Black-footed albatrosses were spared because, in view of their negligible contribution to the aircraft hazard, and of the experimental nature of the program, it was not deemed justifiable to further reduce their low and perhaps decreasing population. Only adult birds were killed; eggs (and the few chicks which hatched) were not destroyed.*

The albatross elimination program was started on 15 January 1958, and was discontinued on 7 March 1958, after having been in operation for 7½ weeks, or 38 working days. It was carried out in accordance with plans agreed upon by the Commanding Officer of the Midway Islands Naval Station, his staff, a representative of the Bureau of Aeronautics, and the Bureau of Sport Fisheries and Wildlife biologists.

The entire program was carried out under the technical supervision of the biologists, who personally gathered and recorded all pertinent data. The killing was done by a crew of 15 enlisted men, permanently assigned to the project, who were under the direction of a chief petty officer. Killing was done with heavy wooden clubs, the birds being dispatched instantly by a strong blow at the base of the skull.

During the first 6 weeks, the killing was carried on during daylight hours (0800-1600). On the night of 11 February, an experimental night kill was conducted. This was so successful that the crew was placed on a night schedule (0100-0930) during the last 2 weeks (25 Feb.-7 Mar.) to facilitate the killing of unemployed birds, many of which successfully eluded the killing crew during the day.

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* Many of the orphaned chicks were "rescued" by members of the killing crew and taken to other parts of the island, where they were given to breeding pairs which had lost their own egg or chick; at this age, chicks are readily accepted by foster parents.

Figure 2. Area in which albatross killing program was conducted on Sand Island, Midway, January - March, 1958.

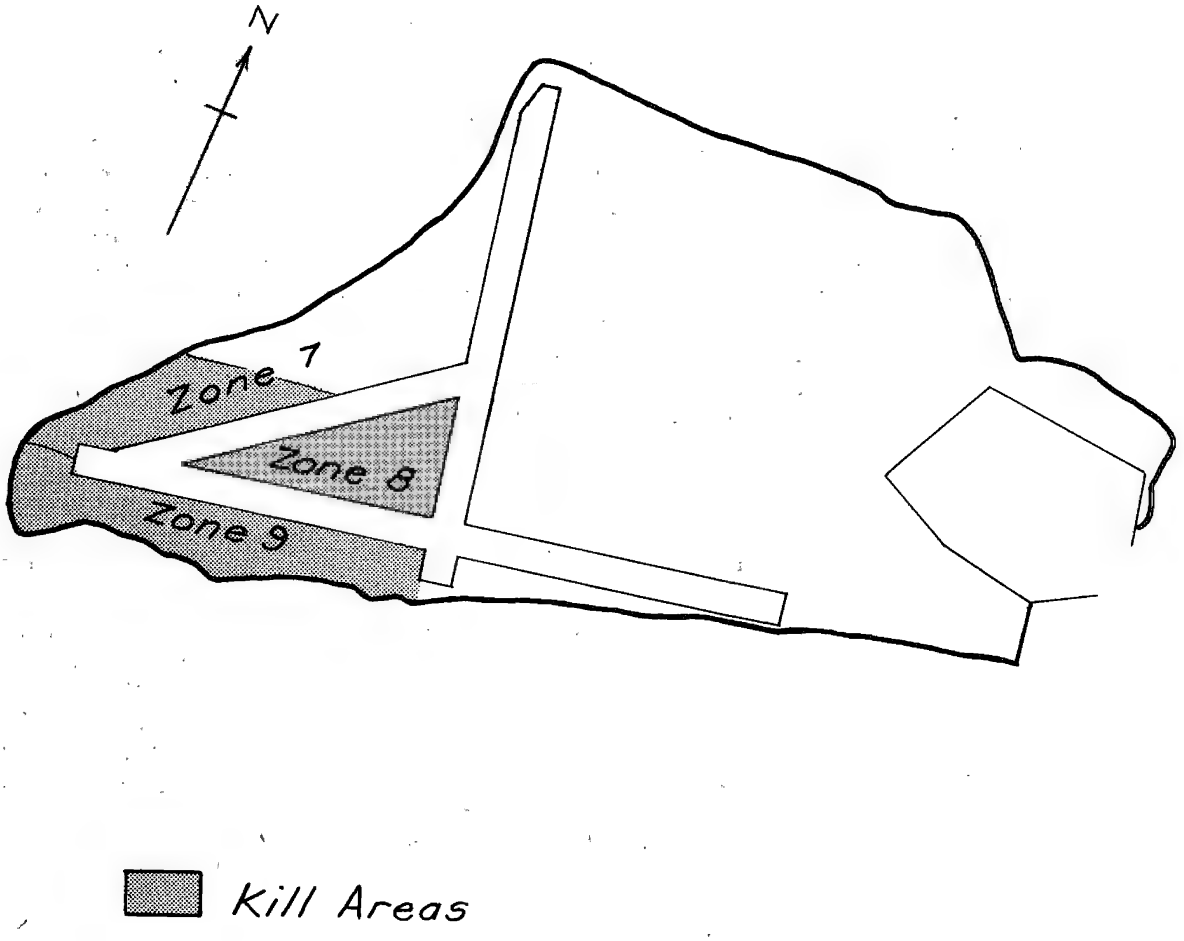


Table 6 contains a summary of the progress of the killing program, grouped into weeks for convenience. A detailed daily report is presented as table 7. Totals of 29,763 Laysan albatrosses, 277 black-footed albatrosses, and 1 hybrid, were killed, a grand total of 30,041 birds.

A total of 3,697 man-hours, not including the biologists' time, was expended on the program. A mean average of 8.2 birds per man-hour were killed. This includes time consumed in all phases of the operation, including killing, pick-up, hauling, burying, etc. A weekly breakdown of man-hours is presented in table 8; the daily totals are included in table 7.

The night kills during the last 2 weeks were not above average as far as birds per man-hour is concerned. However, the total number of birds in the area during that period was much lower than during previous weeks. Also, while the birds are much easier to approach and kill at night, they do not move around much, and there is no influx of new birds arriving from the sea during the night; therefore, most of the birds on the area were eliminated during the first few hours, and very few could be found towards morning.

Table 6.--Weekly Summary of Killing Program

Number of birds killed

	Zone 8 Black-foots	Zone 8 Laysans	Zone 9 (N) Laysans	Zone 9 (S) Laysans	Zone 7 Laysans	Weekly total	Cumulative total
15-17 Jan.	110	861	1,923	--	--	2,894	2,894
20-24 Jan.	60	412	5,078	--	--	5,550	8,444
27-31 Jan.	11	81	2,848	--	--	2,940	11,384
3-7 Feb.	44	477	1,858*	1,628	221	4,228	15,612
10-14 Feb.	19	464	1,804	1,240	--	3,527	19,139
17-21 Feb.	0	56	1,156	337	2,100	3,649	22,788
24-28 Feb.	21	596	1,715	343	1,148	3,823	26,611
3-7 Mar.	12	213	1,724	211	1,270	3,430	30,041
Total	277	3,160	18,106	3,759	4,739	30,041	

* Includes one hybrid albatross

Table 7.-- Daily Record of Albatross Killing Program

Date	Number killed: Zone 8 Black-foots	Zone 8 Laysans	Zone 9 (North)	Zone 9 (South)	Zone 7	Daily total	Cumulative total	Men	Hours
15 Jan.	110	861	--	--	--	971	971	15	8
16 Jan.	--	--	860	--	---	860	1,831	15	8
17 Jan.	--	--	1,063	--	--	1,063	2,894	15	8
20 Jan.	--	--	1,481	--	--	1,481	4,375	15	8
21 Jan.	42	259	650	--	--	951	5,326	11	8
22 Jan.	1	--	1,008	--	--	1,009	6,335	15	8
23 Jan.	--	--	1,101	--	--	1,101	7,436	15	8
24 Jan.	17	153	838	--	--	1,008	8,444	15	8
27 Jan.	--	--	1,129	--	--	1,129	9,573	15	8
28 Jan.	11	81	496	--	--	588	10,161	8	8
29 Jan.	--	--	513	--	--	513	10,674	8	8
30 Jan.	--	--	202	--	--	202	10,876	14	3
31 Jan.	--	--	508	--	--	508	11,384	12	8
3 Feb.	30	257	1,102	--	121	1,510	12,894	12/10	8
4 Feb.	10	147	323*	--	--	480	13,374	10/9	8
5 Feb.	--	--	---	948	--	948	14,322	12	8
6 Feb.	4	73	43	439	100	659	14,981	9/12	8
7 Feb.	--	--	390	241	--	631	15,612	10	8
10 Feb.	--	--	495	350	--	845	16,457	11/13	8
11 Feb.	--	--	116	175	--	291	16,748	13	4
" " (night)	19	464	375	62	--	920	17,668	13/4	8
12 Feb.	--	--	153	363	--	516	18,184	8/12	8
13 Feb.	--	--	361	66	--	427	18,611	12	8
14 Feb.	--	--	304	224	--	528	19,139	12/10	8
17 Feb.	--	--	599	187	--	786	19,925	13/12	8
18 Feb.	--	--	--	--	1,047	1,047	20,972	11	8
19 Feb.	--	--	--	--	776	776	21,748	9/11	8
20 Feb.	--	56	331	70	277	734	22,482	12	8
21 Feb.	--	--	226	80	--	306	22,788	10/12	8
24 Feb.	--	--	411	129	339	879	23,667	12/13	8
25 Feb. (night)	20	396	498	45	248	1,207	24,874	13	9
26 Feb. "	--	--	32	11	--	43	24,917	13	4
27 Feb. "	--	104	509	100	210	923	25,840	12	8
28 Feb. "	1	96	265	58	351	771	26,611	13	8
3 Mar. "	4	78	280	41	345	748	27,359	14/13	8
4 Mar. "	4	50	409	40	202	705	28,064	13	8
5 Mar. "	--	24	411	33	249	717	28,781	14	8
6 Mar. "	--	13	282	24	253	572	29,353	14	8
7 Mar. "	4	48	342	73	221	688	30,041	14	8
Total	277	3,160	18,106	3,759	4,739	--30,041--			

(Total Laysan albatrosses - 29,764)

* Includes one hybrid albatross

Table 8.--Summary of Man-hours Expended in the Albatross Killing Program.

Week	Man-hours	Birds killed	Number per man-hour
15-17 Jan. (day)	360	2,894	8.0
20-24 Jan. "	568	5,550	9.8
27-31 Jan. "	386	2,940	7.6
3-7 Feb. "	423	4,228	10.0
10-14 Feb. "	471	3,527	7.5
17-21 Feb. "	452	3,649	8.1
24-28 Feb. (night)	471	3,823	8.1
3-7 Mar. "	548	3,430	6.3
Total	3,679	30,041	8.2

A very large proportion of the birds nesting on the area were killed. Several weeks before the kill, all nests were counted, and one member of each pair (the one incubating at the time) was marked with a red dye spot on the breast. Very few of the dye-marked birds were killed during the last 3 weeks of the program, indicating that the majority had probably been killed. However, in June there were 100 to 200 healthy Laysan albatross chicks in area 9 alone, indicating that between 100 and 400 adult breeding birds escaped the kill.

Based on observed decrease in number of birds in the area, it is apparent that a large majority of the unemployed birds using the area during the killing period also were eliminated. However, it is impossible to say exactly what proportion were eliminated, as there is a continual turnover in the unemployed segment of the population throughout the season as some birds arrive and others return to the sea. The percentage of unemployed birds killed doubtless is less than the percentage of breeding birds eliminated.

One of the most interesting facts brought out by this killing program was the large number of unemployed birds in relation to the breeding population. Evidence gathered last season (Kenyon, et al. 1958) suggested that the unemployed segment of the population was much larger than originally estimated; this was fully confirmed by the 1958 killing program.

In table 9 is presented the calculated breakdown of the kill into breeding and unemployed segments. This is based on total nest counts made in the area before the kill. For purposes of calculation, it is assumed that all breeding birds were killed, which is not entirely true. A minimum of 96 percent were killed however. Therefore the calculated numbers of unemployed birds in the kill are minimal figures.

The north and south sides of zone 9 should perhaps be considered together, as they are separated only by a road. Killing began on the north side 12 days before proceeding on the south side. Therefore, many of the unemployed birds which frequented both sides of the road were eliminated while killing was being conducted on the north side only. This doubtless explains the difference in calculated proportions of unemployed birds on the two sides of the road. If the data for the north and south sides are combined, the ratio of unemployed birds to breeding birds in zone 9 is 148:100.

As explained above, the kill figures for unemployed birds (and thus also the ratios of unemployed birds to breeding birds) are minimal. In order to determine the size of the unemployed population, we must add to these figures the following: (1) The number of breeding birds which escaped the kill (since it was arbitrarily assumed that all breeding birds were killed, the total of unemployed birds must be increased by this number); (2) the number of unemployed birds which escaped the kill; and (3) the number of unemployed birds at sea which will utilize the area later in the season. None of these figures are known, and it is not possible, with the information now available, to make reasonable estimates for them.

Table 9.--Breeding Population, Total Kill, and Calculated Kill of Unemployed Birds in Albatross Elimination Area.

Area	Number of nests	Breeding population	Number killed	Calculated unemployed birds killed	Ratio of unemployed to breeding birds
Zone 8 (blackfoots)	89	178	277	99	56:100
Zone 8 (Laysans)	632	1,264	3,160	1,896	150:100
Zone 9 (north)	3,331	6,662	18,106	11,444	172:100
Zone 9 (south)	1,076	2,152	3,759	1,607	75:100
Zone 7	326	652	4,739	4,087	627:100
Total (Laysans only)	5,365	10,730	29,764	19,034	177:100

One factor which might tend to increase the apparent proportion of unemployed birds is the killing of birds which have settled temporarily on the kill area, but which normally utilize other territory. This is believed to be negligible for the following reasons: (1) There was no noticeable decrease of unemployed birds in other parts of the island, even in areas contiguous to the kill area (in zone 7, for example); (2) the number of banded birds killed, which had been banded in other areas, was very small (unfortunately, sufficient data are not

available concerning the number of banded birds presently in the population, and the size of the population, to calculate what proportion may have come from other areas); and (3) most unemployed birds seem to be almost as strongly attached to a particular site as are breeding birds (see Kenyon et al. 1958).

One fact was made exceptionally clear from this killing program: The number of unemployed albatrosses far exceeds what was previously thought. Original estimates were about 15 percent of the breeding population (Kenyon et al. 1958); it is now evident that the number of unemployed albatrosses exceeds the breeding population, perhaps by as much as 100 percent. Many of these unemployed birds spend only relatively short periods on the island and there is a steady turnover throughout the season.

With the present lack of knowledge of albatross population dynamics, it is impossible to determine the status of these unemployed birds in the population. It seems likely that a large proportion of them belong to the 4-to 7-year age classes -- immature birds which have returned to the island but have not yet reached breeding age. Present evidence indicates that approximately 67 percent of the breeding population nests each year (see Ecological and Life History Studies -- Frequency of Breeding). This eliminates the possibility that the unemployed population is composed largely of older birds which are simply skipping a year at nesting.

If the above suggestion is correct, and the large majority of unemployed birds are in the 4- to 7-year age classes, it indicates that the survival rate (subsequent to successful fledging) during the first 7 years must be very high.

The important implications of such a high survival rate among subadults are that the 1- to 3-year age classes must of necessity (assuming a fairly constant annual increment to the population) be even larger than the 4- to 7-year age classes. It is these younger age classes, which remain at sea throughout the year, that will be contributing to the unemployed population on the islands throughout the next 3 to 5 or more years, and thus contribute to the potential aircraft hazard for some years to come, regardless of the scope or intensity of any immediate killing programs.

Results.--Observations subsequent to the killing program indicated neither a reduction in numbers of albatrosses soaring over the runways adjacent to the kill area (see figs. 4 and 5 and tables 10 and 11), nor a reduction in the frequency of aircraft strikes (see table 4). Under favorable wind conditions, the density of soaring albatrosses equaled, and often exceeded, that observed before the kill.

At no time did the density of soaring albatrosses over the portions of the runway adjacent to the kill area drop anywhere near

as low as the density over the east end of runway 6-24, where the shoulders have been leveled for 750 feet from the centerline.

It is apparent that any killing program, regardless of its magnitude, would not result in an effective reduction in albatross populations during its first season of operation, and could not come even close to eliminating the portion of the population which appear in the air over runways in less than 5 or more years.

Terrain Modification

Data gathered during the 1957-58 season have confirmed the validity of the conclusions reached during the previous season concerning the effectiveness of terrain modification as a technique for reducing the albatross hazard to aircraft (see Kenyon et al. 1958).

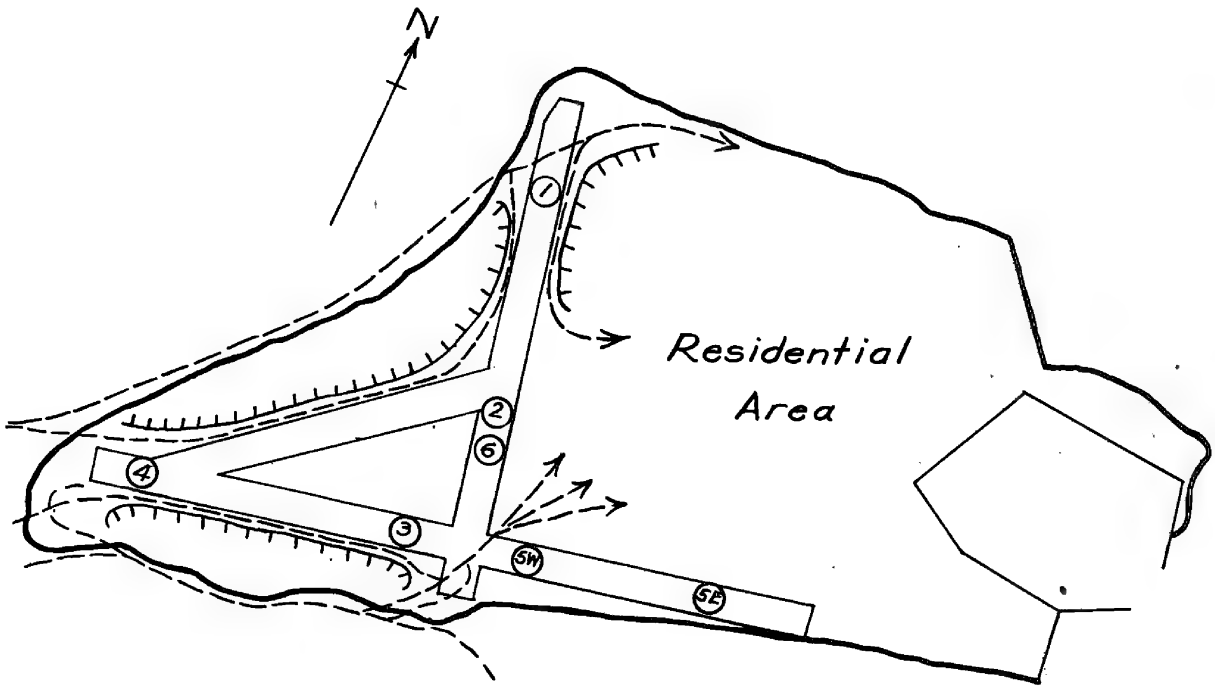
Index counts of birds soaring over the runways were continued throughout much of the 1957-58 season. The counting areas and methods were the same as those used during the previous season (Kenyon et al. 1958) and are not repeated here; the only change was the elimination of station 7, as completion of clearing and leveling in the central triangle made this station virtually identical with station 6 (fig. 3).

Albatross soaring in relation to topography.--Albatrosses show remarkable adaptation for andskill in utilizing air currents while at sea. It is thus only natural that they make use of any favorable air currents while soaring over land on their nesting grounds. This is very obvious even to casual observers. On Sand Island the major soaring areas are along the beach dunes, and inland along the edges of high ironwood growth, dunes, and revetments, which deflect the wind and create updrafts.

The accompanying map (fig. 3) illustrates the present terrain conditions on the runway area on Sand Island. It also shows the major flight routes of soaring albatrosses in relation to terrain features. These were first determined by general observation, and confirmed by runway counts (figs. 4 and 5 and tables 10 and 11).

The accompanying graphs(figs. 4 and 5) indicate the mean number of albatrosses per hour soaring past the counting stations during the 1957-58 season. The counts have been broken down into two periods: November through January (before the killing program), and March through May (after the killing program). However, there is no statistically significant difference between the two periods. The figures indicate the totals for both species of albatross combined. The actual figures on which these graphs are based are presented in tables 10 and 11), in which are presented the individual totals for Laysan and black-footed albatrosses. Black-footed albatrosses constituted only 6.4 percent of all albatrosses counted flying over the runways. This is explained by their smaller population on the island

Figure 3. Terrain conditions and major albatross flight routes on runway area of Sand Island.*



Elevated terrain (dunes, revetments and ironwood growth)

----- Major albatross flight routes

* Use of any individual flight line indicated was dependent on wind direction on that particular day

○ Counting station

and by the fact that most of them inhabit the open beaches which they can reach without flying over the runways.

There is a positive correlation between the height of obstructions and the amount of albatross soaring activity. Compare particularly the density of soaring birds over stations 5e and 5w at the east end of runway 6-24, where the terrain is level and clear, with the density at stations 3 and 4 at the west end of the same runway, where there are high ironwoods and revetments bordering the south side.

This situation is strongly reflected in the frequency of aircraft strikes, which are five times as numerous along the west end of runway 6-24 as along the eastern end (see Albatross Problem in Aircraft Operations -- Location of Strikes in Relation to Terrain and Wind Direction).

All three sides of the central triangle area, zone 8, were formerly major soaring areas (see Kenyon et al. 1958) when the area was covered with dunes, revetments, brush, and trees. This area was cleared and leveled in the late summer of 1957. During the 1957-58 season, albatross soaring was greatly reduced (see figs. 4 and 5, station 6).

Table 10.-- Summary of counts of albatrosses soaring over the runways at index stations prior to the killing program (13 November 1957 to 31 January 1958). Total for both species combined, and (in parentheses) totals for Laysans and black-foots, respectively.

Station	Average number of birds per hour more favorable winds		Number of counts	Average number of birds per hour less favorable winds		Number of counts
1	1,153	(1,047+106)	10	544	(520+24)	13
2	345	(329+16)	11	275	(261+14)	18
3	1,451	(1,160+291)	18	693	(619+74)	11
4	1,322	(1,236+86)	18	232	(226+ 6)	11
5e	37	(34+3)	29	No distinction		
5w	76	(68+8)	29	"	"	
6	424	(395+29)	29	"	"	

Figure 4. Mean number of albatrosses per hour soaring past index points along the runways on Sand Island, during the period November 1957 to January 1958, prior to the killing program.

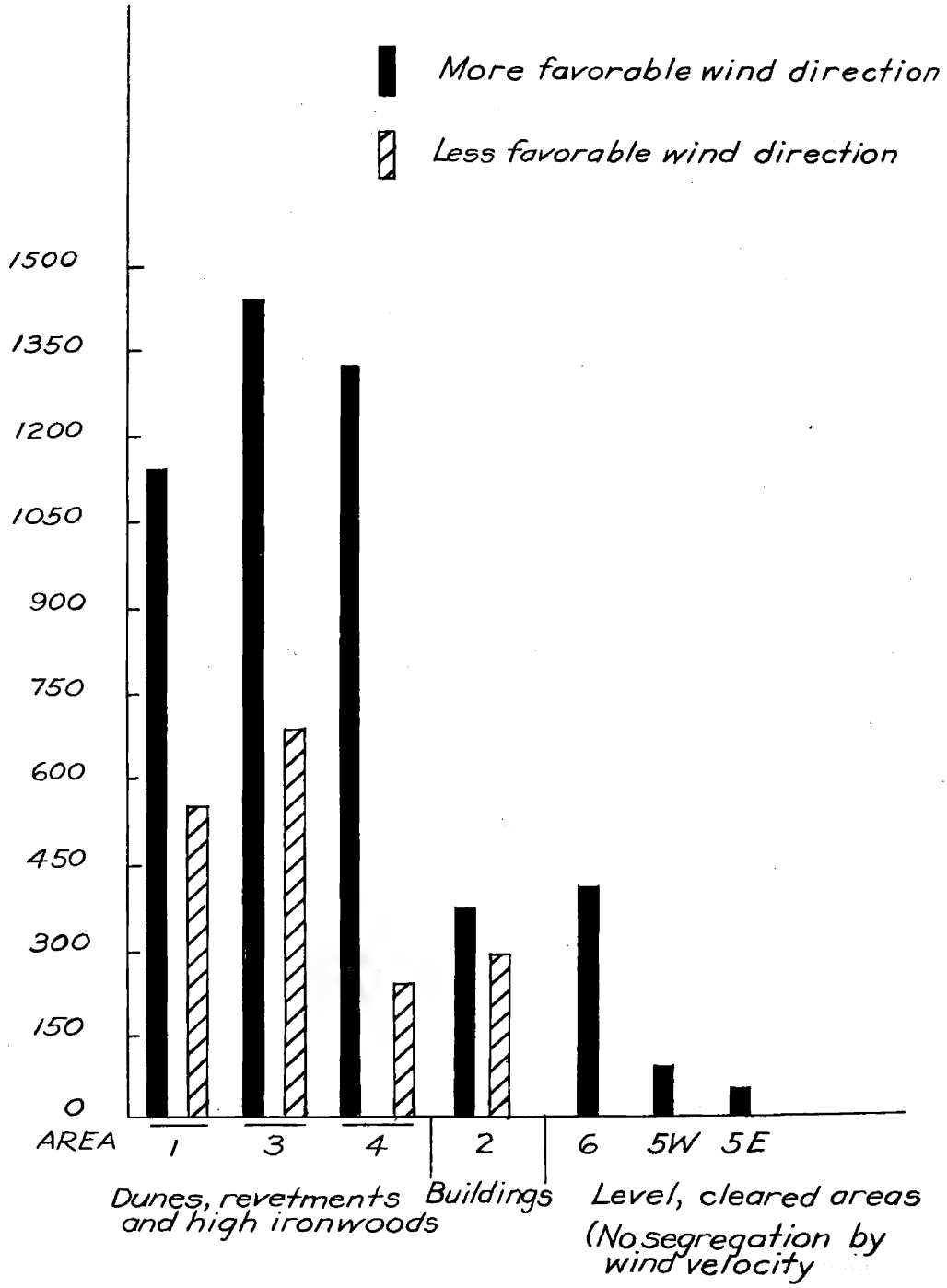


Figure 5. Mean number of albatrosses per hour soaring past index points along the runways on Sand Island, during the period March 1958 to May 1958, immediately following the killing program.

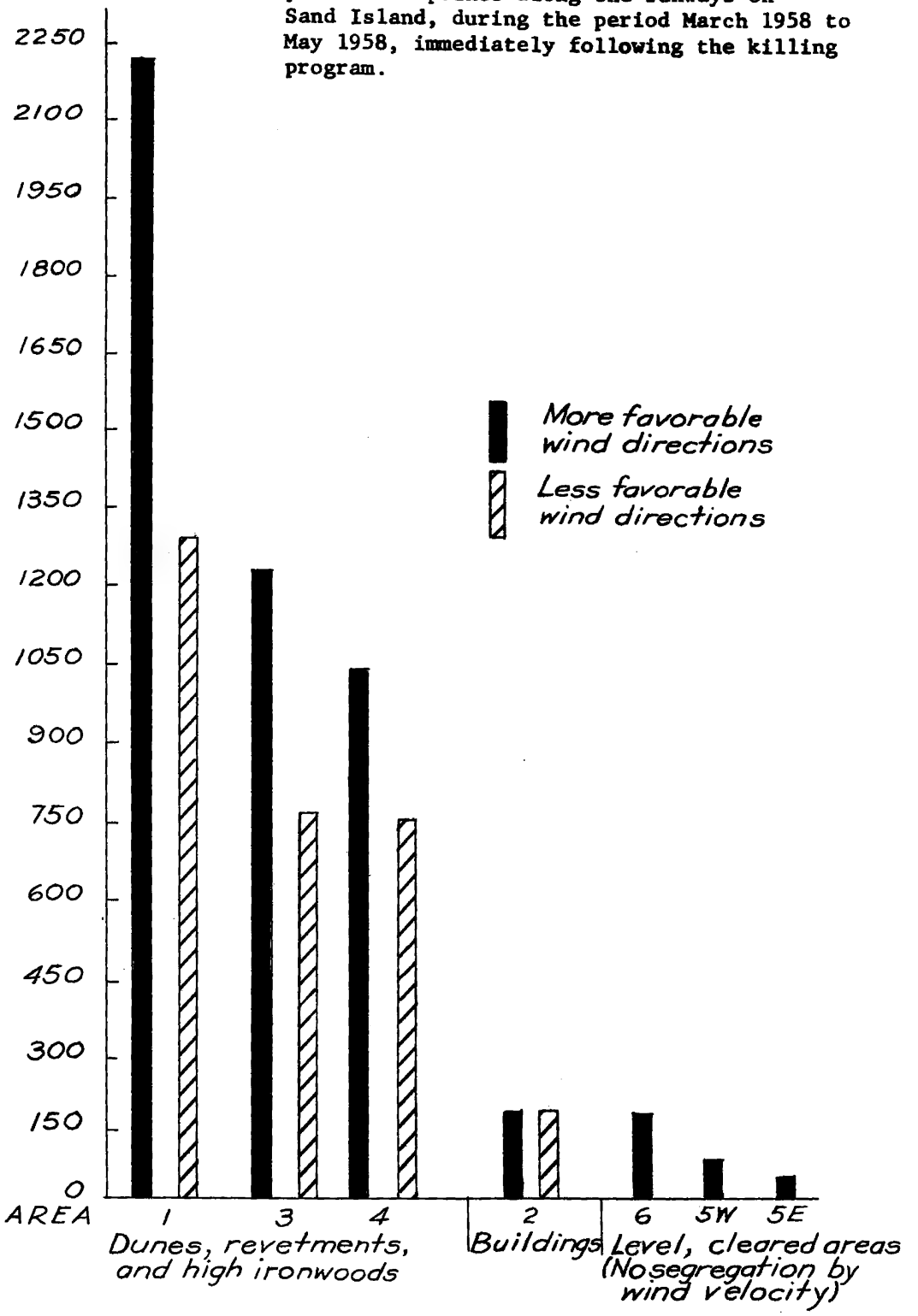


Table 11.--Summary of counts of albatrosses soaring over the runways at index stations after the killing program (3 March 1958 to 2 May 1958). Total for both species combined, and (in parentheses) totals for Laysans and black-foots, respectively.

Station	Average number of birds per hour more favorable winds		Number of counts	Average number of birds per hour less favorable winds		Number of counts
1	2,231	(2,157+74)	8	1,267	(1,241+26)	20
2	170	(164+6)	8	157	(152+5)	20
3	1,231	(1,129+102)	13	753	(660+93)	15
4	1,023	(1,004+19)	13	696	(680+16)	15
5e	11	(9+2)	28	No distinction		
5w	35	(32+3)	28	"	"	
6	150	(138+12)	28	"	"	

Albatross soaring in relation to wind direction.--It is again obvious to the casual observer, and confirmed by runway counts, that albatross soaring is most concentrated on the windward side of high obstructions. If an observer stands at the south end of runway 15-33 and looks to the west on a day with northerly winds, he will see a great concentration of birds soaring along the south side of runway 6-24; on a day with southerly winds, he will notice that the major soaring activity has switched to the area along the south beach, and that very few birds are soaring along the runway.

The runway counts (Figs. 4 and 5, tables 10 and 11) have been segregated according to wind direction. "More favorable winds" include counts made when the wind was blowing from such a quarter as to cross the runway and blow against the dunes, trees, and revetments, at the particular counting station. "Less favorable winds" are those blowing over the obstructions onto the runways. In every case a significantly higher density of soaring birds was recorded under the "more favorable" wind directions. (Stations 5e, 5w and 6 are in level areas, and thus cannot be so segregated.)

This effect of wind direction is also reflected in the frequency of aircraft strikes, which are twice as numerous under "more favorable" wind directions as they are during periods when the wind direction is "less favorable" (see Albatross Problem in Aircraft Operations -- Location of Strikes in Relation to Terrain and Wind Direction).

Albatross soaring in relation to thermals.--It has been suggested that albatross soaring may be influenced by thermal updrafts. Detectable thermal currents exist over Midway runways only on occasional clear, hot, dead calm afternoons in the summer months when albatrosses are scarce or absent. At all other times of the year any thermals which might exist would be so deflected and their effects so overridden by the continual moderate to strong winds that they could not be detected and would be of no use to albatrosses for soaring.

If thermal updrafts played an important role in albatross soaring, large numbers of soaring albatrosses would be expected over the east end of runway 6-24 (stations 5e and 5w); such is not the case (Figs. 4 and 5).

E. Conclusions and Recommendations

(1) At the U. S. Naval Station, Midway Islands, large numbers of Laysan albatrosses create a considerable problem in aircraft operations during part of the year, especially from early November to the middle of December. Bird strikes cause frequent damage to propeller-driven aircraft. Most damage has been minor, but occasionally expensive repairs and long grounding of aircraft are necessary. No crashes or fatal accidents have ever occurred, but at times strikes have impaired operations essential to national defense. If such operations are to continue on a dependable basis, the frequency of albatross strikes must be reduced.

(2) Laysan albatrosses have been extirpated from some of their former nesting islands in the North Pacific, and now breed only on the Leeward Islands, and the island of Niihau, in the Hawaiian Archipelago. The majority nest on Laysan Island and Midway Atoll; 35 percent of the total breeding population nests on Midway. Under these circumstances, no large-scale reduction in numbers would be advisable from the standpoint of perpetuation of these species and only to be considered if absolutely essential to national defense.

(3) Experimental killing programs have demonstrated that it would take a number of years, probably at least 3 to 5, to reduce the population sufficiently to achieve any practical lowering of the strike frequency. Killing of albatrosses within 750 feet of the operational runway reduced neither the number of birds soaring over the runway nor the frequency of strikes. It is concluded that killing is an impractical means of obtaining immediate reduction of the aircraft hazard.

(4) Observations indicate that clearing and leveling the shoulders of the runways for a distance of about 750 feet on either side of the centerline will eliminate updrafts which are conducive to albatross soaring over these runways. This should reduce the strike

frequency by about 80 percent or more. It is concluded that this is the only practical means for immediately reducing the strike hazard.

(5) Black-footed albatrosses should be given complete protection at all times, as they constitute a negligible hazard to aircraft, and their total population is relatively low, and perhaps decreasing.

(6) The possible effect of bird strikes on various types of jet aircraft under varying conditions has been the subject of much controversy and little investigation. Controlled experiments should be conducted to determine the effects of bird ingestion on jet engines. If the regular use of jet aircraft at Midway is contemplated, the necessity of such operations should be carefully weighed against the possible hazards which may result.

(7) As the use of jet aircraft increases, bird strikes are becoming a more acute problem the world over. Perhaps the eventual solution to the problem will be an engineering rather than a biological one.

PART II. SOOTY TERN STUDIES

A. Sooty Tern Populations

No census of sooty terns (Sterna fuscata) could be conducted at Midway this year because of the disturbance caused by a killing program designed to discourage the nesting of these birds on Sand Island. Populations during the 1958 season appeared to be approximately the same as during the 1957 season -- about 150,000 birds on each island.

The following rough estimates of breeding populations of sooty terns on the islands in the western half of the Leeward Chain are based on ground observations at Kure, Midway, and Laysan, and on aerial observations at Pearl and Hermes Reef and Lisianski:

Kure Atoll	0
Midway Atoll	300,000
Pearl and Hermes Reef	50,000
Lisianski Island	150,000
Laysan Island	500,000
Total	1,000,000

Elsewhere in the Hawaiian Archipelago, smaller colonies breed on French Frigate Shoals, Necker, Nihoa, Moku Manu, and Manana. The entire Hawaiian population is conservatively estimated as well over a million. The species is abundant and widespread throughout the tropical Pacific, Indian, and Atlantic Oceans.

On Sand Island, Midway Atoll, clearing operations along the north side of the east end of runway 6-24 reduced to bare sand a large portion of the terns' former nesting ground. This the birds shunned, and the entire colony moved about 100 yards farther back from the runway. However, they still flew in large numbers back and forth across the runway on their way to and from the sea.

On Eastern Island, sooty terns were nesting in areas where they did not nest last year. It is possible, but not proved, that some of the harassed birds on Sand Island moved to Eastern Island to nest.

B. Sooty Terns and Aircraft Operations

Unfortunately the Air Control Tower stopped keeping records of bird strikes at the time the sooty terns returned in April. Because of the tern killing program, the strike frequency was apparently below that of the previous season, when an average of 1.15 birds were killed per landing or takeoff. No damage to aircraft caused by sooty tern strikes was reported.

C. Studies of Control Methods

Habitat Control

Observations have shown that sooty terns will not nest in hard-surfaced areas, areas bare of vegetation, or areas completely grown up in dense brush or trees. Therefore, by modifying the habitat accordingly, the birds can be prevented from nesting in certain areas. However, this does not prevent them from flying across runways which lie between nesting colonies and the sea. For habitat manipulation to be successful as a control measure would require that a very large acreage of Sand Island be rendered unsuitable as nesting grounds. None of the above methods of habitat manipulation would be practical under present circumstances. Hard-surfacing would be too costly, unless the area were also needed for water catchment. To maintain bare sand for any period of time would be impossible and impractical. It would be subject to wind erosion, and would soon begin to develop low herbaceous vegetation, rendering it ideal nesting habitat for the sooty terns. Planting the area to brush and trees would only aggravate the far more serious albatross problem.

Bombing

Several preliminary experiments at bombing were conducted. The bombs were constructed of tin cans (12 oz. to 40 oz.) containing a core of plastic explosive surrounded by shrapnel. The shrapnel used was that available locally -- nails, granite gravel, and fine scrap metal. The bombs were linked together with primer-cord and laid in a pattern about 20 feet apart over the area where the terns were expected to alight. When the birds settled among them, they were detonated electrically by a concealed observer located a safe distance away.

The limited experiments were promising, but the method will have to be perfected by further experiment before it can be recommended. The size and amount of shrapnel used is especially important. Steel shot pellets would be preferable. Further work is necessary to determine the most efficient size bomb, the amount of explosive to use, and the pattern in which they should be laid. It remains to be determined whether they would be most effective during the incubation period, or during the prenesting flocking period.

When perfected, bombing should be a very useful supplement to other control methods, if used sparingly and judiciously.

Shooting and Harassment

During the summer of 1958, the Navy attempted to exterminate the sooty tern colony on Sand Island by shooting and clubbing.

Methods.--The program was started in the traditional nesting area on the north side of the east end of runway 6-24 on 3 June 1958, after nesting was well under way. A crew of five enlisted men, under the direction of a chief petty officer, worked during daylight hours only (0800-1600). Clubs were used until the remaining birds became so harassed that they could not be closely approached. Shooting was then tried. The results are shown in table 12. In addition to reducing the population to some extent this procedure kept the birds harassed. By 17 June, after less than 15,000 (table 12) of an estimated 100,000 birds had been killed, the birds deserted this area.

Concomitant with this desertion, there was a marked increase of birds in a new colony which had started to form before the killing program had begun. This colony was located south of the west end of runway 6-24 (in zone 9), an area not previously utilized by sooty terns.

Killing was commenced in this second colony on 23 June, at which time at least 50,000 birds were present. After approximately 7,000 (table 12) had been killed, this area, too, was deserted.

After the program was terminated on 2 July, the sooty terns did not attempt to renest, and did not settle on the ground. However, each evening for several weeks thereafter, several thousand terns congregated in the air high over their traditional nesting area.

Results.--The sooty tern killing program fell far short of its goal of exterminating the Sand Island tern colony. Only 21,600 of an estimated 150,000 birds were killed.

However, it did harass the birds sufficiently to cause them to leave, thus eliminating for the remainder of the season any potential problem they might create for aircraft operations.

There is every reason to believe that the terns will return to their traditional nesting area next season. However, if such a program of killing and harassment were continued for several seasons, it is believed that the birds may eventually desert the island.

Table 12.--Progress of Sooty Tern Killing Program on Sand Island, 1958.

Colony	Date	Number killed	Rounds ammunition expended
1	3 Jun.	2,500	
1	4	4,500	
1	5	1,600	
1	6	1,400	
1	9	1,200	
1	10	1,100	
1	11	800	
1	12	1,000	
1	17	100	
Subtotal		14,200	4,360
2	23 Jun.	3,000	
2	25	3,000	
2	27	1,000	
2	30	300	
2	2 Jul.	100	
Subtotal		7,400	510
Total		21,600	4,870

D. Conclusions and Recommendations

(1) No factual evidence has been presented to indicate a need for eliminating sooty tern populations on Sand Island as long as jet planes are not used. Although they are frequently struck by aircraft, they are too small to damage piston-driven aircraft. No cases of damage to aircraft resulting from sooty tern strikes were reported during the two seasons of study.

(2) If the regular operation of jet aircraft is contemplated at Midway, experiments should be conducted to determine the effects of tern ingestion on jet engines. Also, the necessity for such operations should be carefully weighed against any hazards that might result, especially in view of the fact that elimination of sooty terns cannot be accomplished in a single season. (Another factor which warrants serious consideration is the presence of several other species of small birds, particularly the extremely abundant petrels and shearwaters, for which no practical control means have been developed.) The use of screens on jet intakes appears to be the only method known at present of eliminating the possible hazards of small bird ingestion.

(3) If the elimination of the sooty tern colony on Sand Island should become necessary, it is recommended that a killing and harassment program, as conducted during the 1958 season, should be continued on an annual basis as long as the birds continue to return to the island. The program should be started as soon as, but not before, egg-laying is well underway (early June). Birds should be clubbed or shot and their eggs broken as long as they remain in the area.

SUMMARY

This report covers investigations by the Bureau of Sport Fisheries and Wildlife in 1957 and 1958 which are a continuation of 1956-57 studies (Special Scientific Report - Wildlife, No. 38) to determine the relation between bird populations and aircraft operations at the U. S. Naval Station, Midway Islands, and to develop a management program that will satisfactorily reduce the hazard to aircraft. The approach to this study included the objective of avoiding a reduction of any bird population to the point of endangering the continuing existence of the species.

Albatrosses

The total world population of Laysan albatrosses (Diomedea immutabilis) is estimated at 1,500,000; this includes about 800,000 sexually mature adult breeding birds, of which about 560,000 nest in any given year. The total world population of black-footed albatrosses (D. nigripes) is estimated at 300,000; this includes about 160,000 sexually mature adult breeding birds, of which about 110,000 nest in any given year.

Laysan and black-footed albatrosses now nest only in the Hawaiian Archipelago (with the exception of a few pairs of black-foots on Tori Shima in the Izu Islands). At least 96 percent of the world population of both species uses only four atolls: Midway, Pearl and Hermes, Lisianski, and Laysan. Midway, utilized by 35 percent of the nesting Laysan albatrosses and 16 percent of the nesting black-footed albatrosses, is second in importance to Laysan Island, which is utilized by 46 percent of the nesting Laysans and 62 percent of the nesting black-foots.

The age at which Laysan and black-footed albatrosses normally return to the breeding grounds for the first time is not yet known. The youngest found to date were 4 years old (one black-footed and one Laysan albatross).

The age at which these species of albatrosses normally begin to nest is not known; the youngest known-age bird found on a nest was a 7-year-old Laysan albatross.

Albatrosses do not habitually nest at the site where they were hatched. The majority return to the same atoll, but may take up residence on another island, or at a different location on the island where they were hatched.

The pair bond in Laysan albatrosses normally remains intact from season to season until broken by the death or disappearance of one of the partners. The establishment of a new pair bond usually takes more than one season.

Pairs return to the same nest site each year if the site remains undisturbed; none have been found to move more than 6 meters.

Approximately 67 percent of the total breeding population will nest in a given year. Birds successful in rearing chicks show less tendency to return (63 percent) the following year than do those that are unsuccessful (87 percent).

The sex ratio of unemployed birds is approximately equal (46 percent males).

Banding recoveries indicate that the pelagic distribution of both species covers the entire North Pacific Ocean from about 25 degrees north latitude to the southern Bering Sea.

Detailed studies of the breeding cycles of both species will be reported in the ornithological journals.

During the 1956-57 season, juvenile mortality (from egg-laying to fledging) of Laysan albatrosses was 40 percent on Sand Island and 33 percent on Eastern Island. Corresponding figures for black-footed albatrosses were 58 percent and 36 percent.

In January 1958, a tidal wave destroyed about 42 percent of the black-footed albatross nests on Sand Island of Midway Atoll, and about 43 percent at Pearl and Hermes Reef. A similar amount of mortality probably occurred throughout the greater part of the Leeward Chain. Laysan albatrosses were virtually unaffected by this high water -- mortality was 6 percent at Pearl and Hermes Reef.

In November, 1957, immediately after the birds had returned to their nesting islands, the frequency of albatross-aircraft strikes reached a peak of 0.40 strikes per daylight landing or takeoff. As soon as nesting was well underway in December, strikes dropped to about half this frequency, and gradually declined throughout the rest of the season.

Seven percent of the strikes (or 1 percent of all daylight landings and takeoffs) resulted in damage to aircraft. Most of this damage was minor; none of it was serious enough to place the aircraft in immediate danger of crashing. No crashes from any cause have ever been reported at Midway during its 23 years of use as an airfield.

Albatross strikes were five times as frequent along portions of the runway bordered by high trees, dunes, and revetments, which create updrafts favorable for albatross soaring, as they were along sections where the shoulders were level.

Strikes were twice as frequent when wind directions were such as to create the strongest updrafts along the runway.

In the course of an experimental killing program in the area within 750 feet of the centerline of the west end of runway 6-24 on Sand Island, 30,041 adult albatrosses (almost all Laysans) were killed. At least 19,133 of these were unemployed birds; the rest were nesting birds, most of which were eliminated.

The killing program did not result in a discernible decrease in the number of birds soaring in the area, or in a reduction in the frequency of strikes. It was concluded that killing albatrosses as a control measure would require a number of years of constant effort before any practical degree of reduction in aircraft hazard could be achieved.

Observations made during the 1957-58 season confirm the conclusions reached the previous season that the most practical means of bringing about an immediate reduction in the number of albatrosses soaring over the runways is to eliminate updrafts by leveling the areas bordering the runway. This reduction might be as much as 80 percent.

Sooty Terns

The sooty tern (*Sterna fuscata*) population at Midway Atoll is about 150,000 birds on each island. Well over a million breed in the western half of the Leeward Chain, from Laysan to Midway. The species is abundant and widespread in all tropical oceanic areas.

Although sooty terns are frequently struck by aircraft, no damage was reported during the last two seasons (1957 and 1958).

During 1958, an attempt was made by the Navy to exterminate the sooty terns on Sand Island by shooting and clubbing them after they had laid their eggs. Only 21,600 were killed, but it did harass the birds sufficiently to drive them from the island for the remainder of the season.

If elimination of sooty terns should become necessary, it is recommended that the killing and harassment be continued on an annual basis for as many years as necessary.

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